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REPORT

HYDROLOGIC ATLAS FOR OHIO

AVERAGE ANNUAL PRECIPITATION, TEMPERATURE, STREAMFLOW, AND WATER LOSS FOR 50-YEAR PERIOD, 1931-1980

by

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TABLE OF CONTENTS

LIST OF FIGURES

Number | Page

LIST OF TABLES

Number | Page

INTRODUCTION

The Hydrologic Atlas for Ohio has been developed as a reference for the basic parameters of the hydrologic cycle. These parameters include precipitation, temperature, streamflow and water loss. All data in this report are based on 50 years of record for each of these parameters from 1931-1980. The data are presented for hydrologic use in determining average annual precipitation, temperature, streamflow, and water loss for point locations in Ohio. Information on average annual lake evaporation and snowfall has been included as supplemental related data. Previous hydrologic assessments were compiled for the base period 1931-1960 (Ohio Department of Natural Resources, 1962) and for the period 1921-1945 (Sanderson, 1950). This study expands that period of record through 1980.

This atlas is designed to be a source of hydrologic data for environmental assessments and investigations. The information should be valuable to ground-water scientists, water-supply engineers, dam construction and design engineers, and other environmental consultants. The atlas should also provide valuable information for planners and developers of municipal and state projects.

Water loss, as used in hydrology and for the purposes of this atlas, is defined as the difference between the average annual precipitation for a drainage area and the average annual streamflow as determined from continuous flow measurements by a stream gauging station for the area. Adjustments for storage, deep seepage and underflow are considered insignificant factors in Ohio for the 50-year base period. Locally collected data will provide the best information for drainage areas of 20 square miles or less.

The precipitation, streamflow and temperature maps were compiled from data collected at observation stations with 50 years of record for the base period 1931-1980. These data have been supplemented by including stations with 25 to 49 years of record through extrapolation using data from nearby stations. Data for the period of record at the shorter term stations were correlated with those for the same period at one or more nearby stations. Quantities for missing years at shorter term stations were obtained from those correlations and used to complete the record and compute the 50-year averages. Use of these data provided more detailed coverage for the entire state. The author has determined that similar hydrologic investigations using this method have contained less than five percent error in extrapolated data.

PRECIPITATION

The precipitation map represents the 50-year average annual precipitation for the base period. Data used in the preparation of the map were obtained from National Oceanic and Atmospheric Administration (NOAA) files for 1931-1980, from Miller (1969), and from unpublished climatological data summaries of The Miami Conservancy District for 1931-1980. The map is based on records from 205 observation stations in Ohio and adjacent states. Values at 38 of these stations have been estimated. The precipitation for each station is measured by an 8-inch diameter standardized Weather Bureau-type rain gauge. Gauges are from 15 to 20 miles apart. Each observation point represents an area of 225 to 400 square miles. The 50-year average annual precipitation for each station was plotted and isohyetal lines (lines of equal precipitation) were drawn as shown on Plate I. Precipitation estimates from the map are considered to be most accurate for areas of 200 square miles or more (Ohio Department of Natural Resources, 1962).

The map shows a wide variation in precipitation over Ohio (Plate I). The general trend is for precipitation to be greatest in the south and east, diminishing in amount toward the northwest. Miller and Weaver (1969) state that the southward and eastward increase in precipitation over the state may be attributed to differences in temperature, supply of moisture, and topography.

Most of Ohio's terrain is relatively flat, representing the glaciated area of the state, while the remaining one-fourth is hilly or undulating, and representative of unglaciated areas in the Appalachian Plateau region. Although the relatively flat terrain is considered to have minimal effect on precipitation, some seasonal anomalies are noted in the southwest around Hillsboro and Wilmington and in the north central area around Ashland and Mansfield. Considerable effect on precipitation is apparent in the areas adjacent to Lake Erie east of Cleveland to the Pennsylvania border, an area referred to as the snowbelt region. The proximity of eastern Ohio to the Appalachian Mountains is also considered to affect precipitation.

Average annual precipitation ranges from a high of nearly 44 inches in the northeast near Chardon (Geauga County) and in the southwest near Hillsboro (Highland County), to less than 30 inches at Put-in-Bay on South Bass Island (Ottawa County). Snowfall ranges from greater than 100 inches in the northeast, east of Cleveland, to less than 20 inches in the south along the Ohio River (Figure 1).

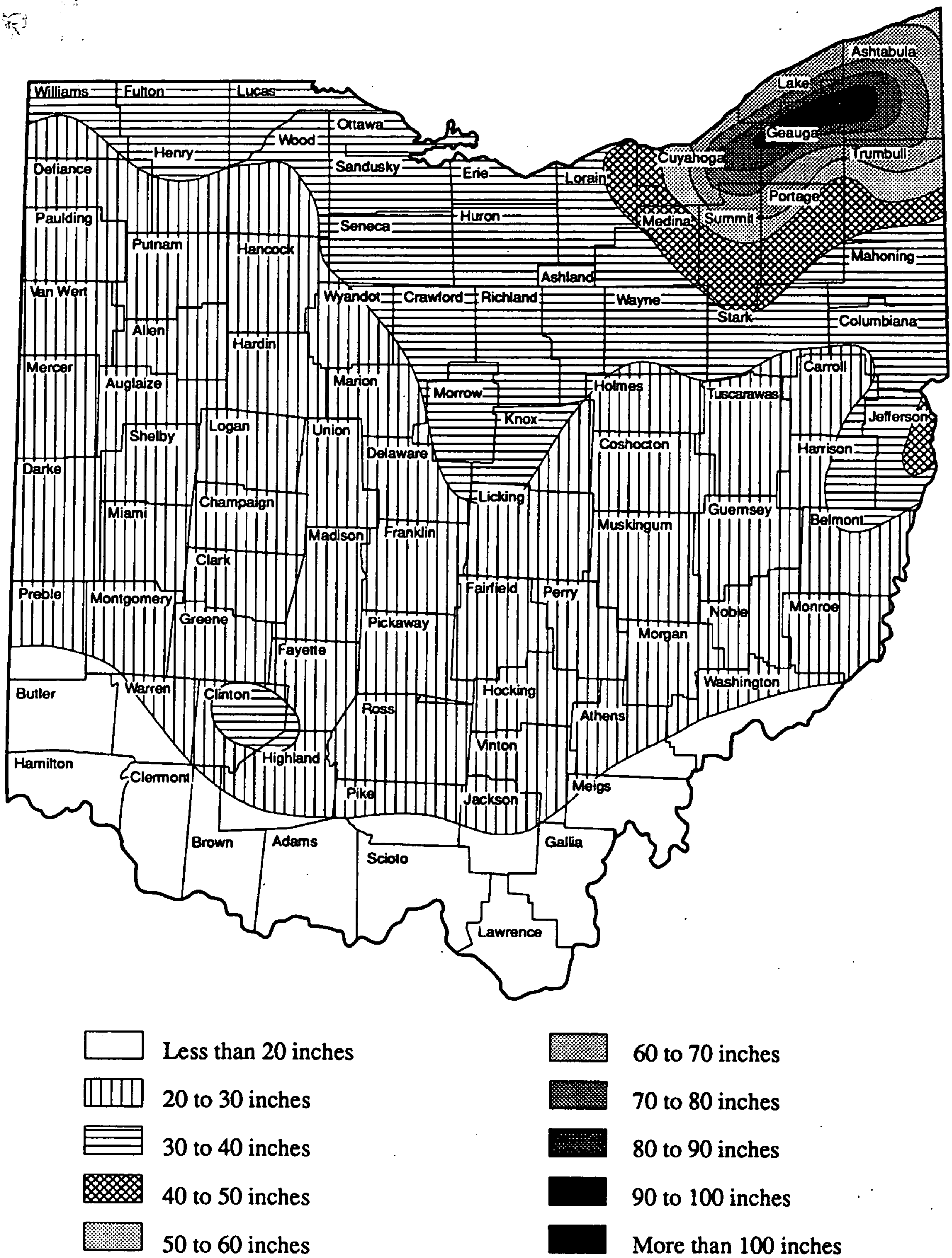

Figure 1. Mean snowfall for winter season, 1936-1965 (after Miller and Weaver, 1971)

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TEMPERATURE

The temperature map represents the 50-year average annual temperature for the base period. Data for this map were obtained from the NOAA files for 1931-1980 and from Miller (1969). The map is based on records for 106 observation stations in Ohio and adjacent states. Data for a number of these stations were adjusted for the base period 1931-1980 by extrapolation from adjacent station records. The temperature data were plotted and isotherms (lines of equal temperature) were drawn as shown on Plate II.

Average annual temperatures across the state generally decrease from south to north. Temperatures range from greater than 56 degrees Fahrenheit at the southern tip near Chesapeake (Lawrence County) on the Ohio River, to less than 48 degrees Fahrenheit in the north central area near Charles Mill Dam (Richland and Ashland Counties) and in the northeast near Dorset (Ashtabula County). Temperatures also range to less than 49 degrees Fahrenheit in the extreme northwest (Fulton and Williams Counties).

STREAMFLOW

The streamflow map represents the 50-year average annual streamflow for the base period. The map is based on records from 141 stream gauging stations operated by the U.S. Geological Survey (USGS), Water Resources Division, Ohio District, and 17 additional gauging stations operated by other USGS, Water Resources Divisions, in adjacent districts. Records for 60 gauging stations cover the full 50-year base period. Records for 81 stations have been extrapolated to represent 50 years from actual records ranging from 20 to 49 years of data to help provide complete coverage of the state. Extrapolation involved correlating data at shorter term stations with data from nearby stations with records which covered the 1931-1980 base period.

Average annual streamflow in cubic feet per second per year was converted to inches of runoff and plotted at the centroid of the drainage area above each gauging station. Runoff from the intervening area was computed and plotted at the centroid of the respective drainage area for basins with more then one gauging station. Based on this method, streamflow isopleths were drawn as shown on Plate III.

Ground water in Ohio usually recharges from or discharges to perennial streams on a seasonal basis. Therefore, isopleths for small drainage areas do not represent the flow that would be measured at a stream gauging station at that point. In small drainage areas, this unmeasured discharge may constitute a substantial portion of the total flow. Thus, isopleths for small drainage areas represent the contribution of that area to streamflow at a downstream gauging station. This phenomenon is observed at many gauging stations in Ohio.

Average annual streamflow across the state ranges from a maximum of more than 21 inches in the northeast in the Ashtabula River basin and 16 to 18 inches in the south along the Ohio River to a minimum of 10 inches in the northwest in the Maumee River basin. The lake effect on climatic conditions east of Cleveland results in greater precipitation and subsequent greater runoff for that region.

Another factor to be considered is the effect that regional ground-water flow may have on the streamflow of small drainage areas. This is especially true where the ground-water divide does not coincide with the topographic divide. Thus, one drainage area may receive ground-water flow from another drainage basin which ultimately contributes to that basin's streamflow. Some of the anomalies in the streamflow map may be caused by such hydrologic conditions.

The streamflow map (Plate III) provides a general overview of annual streamflow conditions in Ohio. Since most of the gauging station records in Ohio are for areas of more than 200 square miles, average annual streamflow for such areas would often conceal local irregularities. The accuracy of estimates for drainage areas of 100 square miles or less may be questionable. In the case of small drainage areas, the original data should be examined more closely.

WATER LOSS

Water loss is defined as the difference between the precipitation over a drainage area and the streamflow from the area. The average annual water loss map was constructed by subtracting the average annual streamflow (Plate III) from the average annual precipitation (Plate I). Water loss determinations were made by superimposing the average annual streamflow map over the average annual precipitation map and subtracting at points where streamflow isopleths and isohyetal lines intersect. Water loss isopleths were drawn to indicate average annual water loss for the base period as shown on Plate IV. Validation of water loss in selected drainage areas was determined by planimetering precipitation values and subtracting average annual runoff. This calculated water loss was then checked at the centroid of the corresponding drainage area on the water loss map to determine if these values were within an acceptable margin of error.

Average annual temperature is also a factor in water loss. Studies by the USGS indicate a direct relationship between average annual temperature and average annual water loss (Williams, 1940). A comparison of average annual water loss and average annual temperature for selected basins in Ohio is shown in Figure 2. Water loss for most larger drainage basins plotted very close to the trend line shown in Figure 2. Water loss for small drainage areas deviated from the trend line as shown by station no. 03125000, Home Creek near New Philadelphia, a 1.64-square-mile drainage area showing high water loss and low streamflow. This data can be compared to station no. 03115500, Little Muskingum River near Fay, a 259-square-mile drainage area showing low water loss and high streamflow. These deviations are typical of many unglaciated and hilly areas in the eastern and southeastern parts of the state.

EVAPORATION FROM WATER SURFACES

Evaporation from water surfaces does not show a significant influence on streamflow. Water surface areas in the drainage area of a gauging station often amount to less than five percent of the total area. However, increases in water loss by evaporation for short periods of a few months on small drainage areas are significant and should be accounted for in the design of small lakes and reservoirs. The data for these areas should be supplemented with more localized, seasonal data available from recent NOAA climatological publications.

The loss of water by evaporation from open water surfaces over an area is of considerable magnitude in Ohio (Farnsworth et al., 1982). A map of free water surface evaporation (shallow lake), 1956-70 (Figure 3), was constructed from pan evaporation data collected from stations in Ohio. Although free water surface evaporation is a somewhat theoretical term, it is of interest to users because it also represents potential evaporation from moist soils and potential evapotranspiration from vegetation. Free water surface evaporation for Ohio is usually considered to range from 73 to 77 percent of the average pan evaporation (Farnsworth and Thompson, 1982).

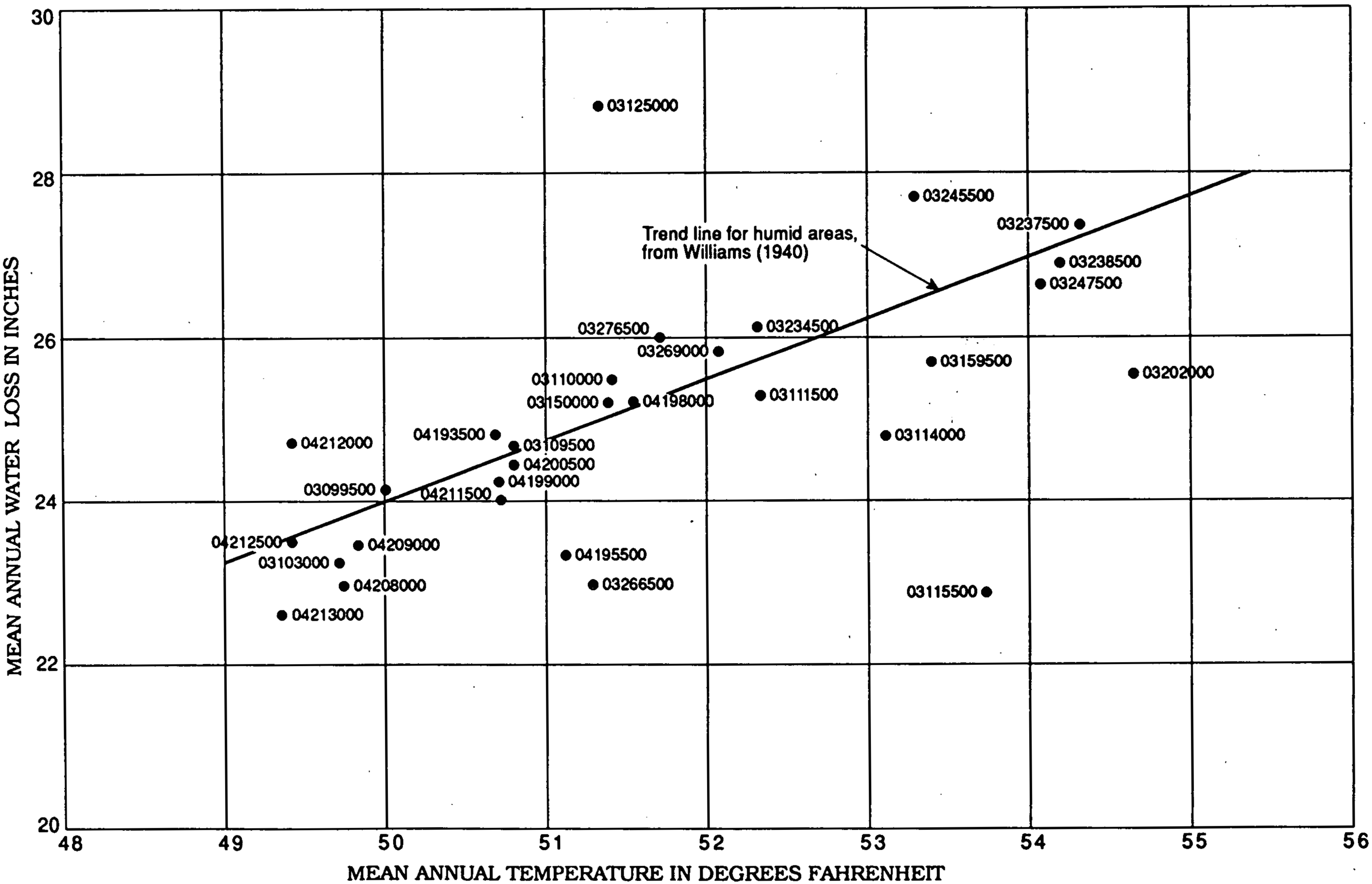

Figure 2. Comparison of mean annual water loss and mean annual temperature for selected basins in Ohio (after Ohio Department of Natural Resources, 1962).

Figure 3. Annual free water surface evaporation (shallow lake), 1956-1970 (after Farnsworth et al., 1982).

Few pan evaporation data stations exist in Ohio and their records are usually incomplete. Based upon the availability of data, the period 1956 to 1970 was considered to be the longest period of complete data coverage. Table 1 shows available mean monthly Class A pan evaporation for stations in Ohio (Farnsworth and Thompson, 1982).

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TABLE 1. MEAN MONTHLY, AND SEASONAL CLASS A PAN EVAPORATION (IN INCHES) FOR STATIONS WITH 10 YEARS OR MORE OF RECORD FOR BEST MONTH* (AFTER FARNSWORTH AND THOMPSON, 1982)

Station Location	Station Index No.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	May-Oct **	Record Began Mo/Yr	Latest Data Mo/Yr
Charles Mill Lake (or Dam)	1466	3.59	4.98	5.90	6.21	5.48	4.01	2.65		29.23	4/39	10/79
40° 44', 82° 22'		39	41	41	41	41	41	41				
		19	16	9	10	8	12	17		7		
Columbus University Farm	1782	5	5.69	6.83	7.27	6.23	4.76	3.29		34.07	4/58	10/70
40° 00', 83° 03'		8	13	14	13	14	13	12				
		***	15	11	15	11	34	27		11		
Columbus (Ohio State Univ)	1788	3.33	4.45	5.29	5.66	4.79	3.53	2.14		25.86	6/18	11/55
40° 00', 83° 00'		35	36	37	38	38	37	38				
		***	***	***	***	***	***	***		***		
Coshocton Agric Rsch Station	1905	4.99	6.01	6.71	7.05	6.21	4.72	3.59		34.29	4/56	9/79
40° 22', 81° 48'		13	23	24	23	24	21	20				
		***	***	***	***	***	***	***		***		
Dayton	2067	4.04	5.65	6.77	7.06	6.20	4.63	2.86		33.17	4/37	10/69
39° 45', 84° 10'		32	31	32	32	32	32	32				
		18	15	7	11	10	9	16		6		
Deer Creek	2090	5	6	7	6.63	6	3.67	3		32	6/70	11/79
39° 30', 83° 13'		7	9	9	10	9	10	10				
		***	***	***	***	***	***	***		***		
Senecaville Lake (or Dam)	7559	4.35	5.52	6.32	6.35	5.73	4.30	2.99		31.21	4/39	10/79
39° 55', 81° 26'		34	38	38	38	39	39	37				
		20	14	10	24	7	15	38		8		
Tom Jenkins Lake	8378	4	5.08	5.39	5.45	4.72	3.61	2.52	1	26.77	7/53	11/79
39° 33', 82° 04'		9	26	26	27	27	27	26	7			
		***	12	9	11	10	11	15	***	6		
Wooster Exp Station	9312	4.03	5.23	6.31	6.80	5.81	4.35	2.71		31.21	7/16	10/79
40° 47', 81° 36'		36	48	48	49	49	51	50				
		19	17	10	12	10	12	21		8		

* First line of data in the table for each station is mean evaporation in inches; second line is the number of years of record per month; third line is the coefficient of variation in percent (computed only where there are 10 years or more of record during 1956-1970).

** Sum of monthly means

*** Insufficient data between 1956 and 1970 to compute the coefficient of variation

ACKNOWLEDGEMENTS

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REFERENCES

Farnsworth, R. K., Thompson, E. S., and Peck, E. L., 1982. Evaporation Atlas for the Contiguous 48 United States, NOAA Technical Report NWS 33, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, 26 pp., 4 plates.

Farnsworth R. K., and Thompson, E. S., 1982. Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States, NOAA Technical Report NWS 34 , U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, 82 pp.

Miller, M. E., 1969. Climatic Guide for Selected Locations in Ohio. Ohio Department of Natural Resources, Division of Water, and U.S. Department of Commerce, Environmental Science Service Administration.

Miller, M. E., and Weaver, C.R., 1969. Monthly and Annual Precipitation Probabilities for Selected Locations in Ohio. Research Bulletin 1017, Ohio Agricultural Research and Development Center, 41 pp.

Miller, M. E., and Weaver, C.R., 1971. Snow in Ohio. Research Bulletin 1044, Ohio Agricultural Research and Development Center, 23 pp.

Sanderson, E.E., 1950. The Climatic Factors of Ohio's Water Resources. Bulletin 15, Ohio Department of Natural Resources, Division of Water, 280 pp.

Ohio Department of Natural Resources, Division of Water, 1962. Hydrologic Atlas of Average Annual Precipitation, Temperature, Streamflow and Water Loss in Ohio. Water Inventory Report No. 13, 4 pp., 4 plates.

Williams, G.R., 1940. Natural Water Loss in Selected Drainage Basins. United States Geological Survey, and Ohio Department of Natural Resources, 62 pp.

UNPUBLISHED DATA

The Miami Conservancy District. Precipitation data for the Miami River Basin, 1931-80. The Miami Conservancy District, Dayton.

National Oceanic and Atmospheric Administration. Climatic Data-Ohio, 1931-80. National Weather Service, U.S. Department of Commerce, Washington, D.C.

United States Geological Survey. Stream gauging records, 1931-80. Water Resources Division, Ohio District, Columbus.